No. 5 - 2008.05.23, updated 2008.11.25:

Four lectures on the general history of astrometry

overview, handouts and abstracts - 2008-11-25

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Lecture No. 1. 45 minutes

Astrometry and photometry from space: Hipparcos, Tycho, Gaia

The introduction covers 2000 years of astronomy from Ptolemy to modern times. The Hipparcos mission of the European Space Agency was launched in 1989, including the Tycho experiment. The Hipparcos mission and the even more powerful Gaia mission to be launched in 2011 are described.

The lecture has been developed over many years and was held in, e.g., Copenhagen, Vienna, Bonn, Düsseldorf, Vilnius, Oslo, Nikolajev, Poltava, Kiev, Thessaloniki, Ioannina, Athens, Rome, Madrid, Washington, and Charlottesville - since 2007 in PowerPoint.

Handouts with 2 and 6 slides per page:
www.astro.ku.dk/~erik/AstrometrySpace2.pdf. and AstrometrySpace.pdf.

Lecture No. 2: 30 minutes. An alternative to No. 1, for astronomers and data engineers. It may be expanded to 45 minutes by including more on Gaia.

From punched cards to satellites: Hipparcos, Tycho, Gaia

A personal review of 54 years development of astrometry in which I took active part.

The lecture was developed in 2007 in PowerPoint and was held in Catania and Madrid.

Handouts at: /PunchedCards2.pdf. and /PunchedCards.pdf.

Lecture No. 3: 45 minutes. Suited for a broad audience, including non-astronomers

The Depth of Heavens - Belief and Knowledge during 2500 Years

The lecture outlines the structure of the universe and the development of science during 5000 years, focusing on the distances in the universe and their dramatic change in the developing cultural environment from Babylon and ancient Greece to modern Europe.

The lecture was first held in 2002, and since 2007 in PowerPoint. Held in Copenhagen, Vilnius, Nikolajev, Athens, Catania and Madrid.

Handouts at: /DepthHeavens2.pdf and /DepthHeavens.pdf

An article with the same title as the lecture appeared in Europhysics News (2004) Vol. 35 No.3. Here slightly updated, 2004.02.20: www.astro.ku.dk/~erik/Univ7.5.pdf

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Lecture No. 4: included on 2008.11.25, 45 or 30 minutes.

400 Years of Astrometry: From Tycho Brahe to Hipparcos

The four centuries of techniques and results are reviewed, from the pre-telescopic era until the use of photoelectric astrometry and space technology in the first astrometry satellite, Hipparcos, launched by ESA in 1989.

The lecture was presented as invited contribution to the symposium at ESTEC in September 2008: **400 Years of Astronomical Telescopes: A Review of History, Science and Technology.** The report to the proceedings is included as No. 8 among the "Contribution to the history of astrometry ".

Organization:

Each lecture may stand alone, depending on the audience. The combination of lecture No. 3 (The depth of heavens) and No. 2 (From punched cards...) may however be recommended. That was the arrangement in April 2008 at ESAC, the place near Madrid where Gaia data reduction software is being developed. No. 3 was given before noon where everyone in the ESAC community was invited, and No. 2 was held in the afternoon for a more specialised astronomer audience, in both cases the attendance was very satisfactory.

Abstracts of the four lectures

Lecture No. 1. 45 minutes

Astrometry and photometry from space: Hipparcos, Tycho, Gaia

With an historical introduction

The introduction covers 2000 years of astronomy from Ptolemy to modern times.

The Hipparcos satellite of the European Space Agency was the first satellite specifically designed for astrometry. It obtained high-precision astrometry for 120 000 stars in 3 years of observations (1989-1993), published 1997 in the Hipparcos Catalogue. For 21000 stars the precision of distances is better than 10 per cent. Photometry in a broad spectral band was obtained, with a median precision of 0.0015 mag. The Tycho experiment onboard the satellite gave astrometry and two-colour photometry for 2.5 million stars, published in 2000 in the Tycho-2 Catalogue, including proper motions.

The Gaia satellite is also an ESA project and will be launched in 2011. It will obtain high-precision astrometry and multi-colour photometry for all the one billion stars brighter than V=20 mag. Astrometric precision for bright stars: 10 microarcsec. Gaia data will have the precision necessary to quantify the early star formation, and subsequent dynamical, chemical and star formation evolution of the Milky Way Galaxy.

Since all point sources brighter than V=20 mag will be detected and measured astrometrically and photometrically, GAIA will make a deep survey of about one million small objects in our Solar System.

Lecture No. 2: 30 minutes. An alternative to No. 1, for astronomers and data engineers. It may be expanded to 45 minutes by including more on Gaia.

From punched cards to satellites: Hipparcos, Tycho, Gaia

A personal review of 54 years

The Hipparcos satellite of the European Space Agency was the first space mission to perform astrometry, the art of measuring positions, motions and distances to stars. Hipparcos succeeded 1989-93 to measure a million times more efficiently than ground-based instruments in the 1950s when I studied at the Copenhagen University. A personal review is presented of this development in which I took active part, for instance by proposing in 1960 the principle of astrometric measuring with a slit system and photon counting, used for 40 years on meridian circles and for Hipparcos/Tycho, until CCDs became mature. This led to the Gaia mission to be launched in 2011 and it will improve astrometry by yet another million times. The scientific impact of the missions is illustrated.

Lecture No. 3 45 minutes. Suited for a broad audience, including non-astronomers

The Depth of Heavens - Belief and Knowledge during 2500 Years

The lecture outlines the structure of the universe and the development of science during 5000 years, focusing on the distances in the universe and their dramatic change in the developing cultural environment from Babylon and ancient Greece to modern Europe.

For Dante Alighieri (1265-1321) the spiritual cosmos contained the Heavens, Earth, and Hell, and it was compatible with the physical cosmos known from Aristotle (384-322 B.C.). Dante's many references in his Divine Comedy to physical and astronomical subjects show that he wanted to treat these issues absolutely correct. Tycho Brahe proves three hundred years later by his observations of the Stella Nova in 1572 and of comets that the spheres of heavens do not really exist. It has ever since become more and more difficult to reconcile the ancient ideas of a unified cosmos with the increasing knowledge about the physical universe.

Ptolemy derived a radius of 20 000 Earth radii for the sphere of fixed stars. This radius of the visible cosmos at that time happens to be nearly equal to the true distance of the Sun, or 14 micro-light-years. Today the radius of the visible universe is a million billion (10 to the power 15) times larger than Ptolemy and Tycho Brahe believed.

Lecture No. 4 included on 2008.11.25: 45 or 30 minutes

400 Years of Astrometry: From Tycho Brahe to Hipparcos

Galileo Galilei's use of the newly invented telescope for astronomical observation resulted immediately in epochal discoveries about the physical nature of celestial bodies, but the advantage for astrometry came much later. The quadrant and sextant were pre-telescopic instruments for measurement of large angles between stars, improved by Tycho Brahe in the years 1570-1590. Fitted with telescopic sights after 1660, such instruments were quite successful, especially in the hands of John Flamsteed. The meridian circle was a new type of astrometric instrument, already invented and used by Ole Rømer in about 1705, but it took a hundred years before it could fully take over. The centuries-long evolution of techniques is reviewed, including the use of photoelectric astrometry and space technology in the first astrometry satellite, Hipparcos, launched by ESA in 1989. Hipparcos made accurate measurement of large angles a million times more efficiently than could be done in about 1950 from the ground, and it will soon be followed by Gaia which is expected to be another one million times more efficient for optical astrometry.

The lecture was presented as invited contribution to the symposium at ESTEC in September 2008: **400 Years of Astronomical Telescopes: A Review of History, Science and Technology.** The report submitted to the proceedings is included as No. 8 among my “Contributions to the history of astrometry”.